

## Integrating bioinformatics in elementary and secondary education: teacher's perceptions

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### Abstract

The new challenges in life science research highlight the need of updating science teaching practices. The aim of this study was to unveil teacher's perceptions about bioinformatics and to identify learning opportunities. In this regard, a questionnaire was applied to two different groups of secondary school level science teachers. Group A (n=11) answered the questionnaire before receiving training to implement the bioinformatics activity "Mining the genome: using bioinformatics tools in the classroom to support students' discovery of genes" in their classes. This initial survey was important to prepare teaching materials (<https://bioinformaticaula.wixsite.com/bioinformatica-pt>) as well as to revise the questionnaire. An improved version of the questionnaire was applied to Group B (n=13) which included a group of teachers that attended the training course "Adequacy of bioinformatics tools to elementary and secondary education" (CCPFC/ACC-88413/16) at Faculty of Sciences, UP. IBM SPSS was used to analyze the quantitative data, and a content analysis was carried out for qualitative data. All participant teachers (Groups A and B) demonstrate a high interest in bioinformatics, agreeing that it assumes a key role in biological research and highlight the need of introducing curricular framed bioinformatics activities at elementary and secondary school levels. When teachers were asked about constraints to implement bioinformatics activities in the classroom, they mainly mentioned logistics problems, namely, poor internet access and lack of computers. However, the observations recording the implementation of the bioinformatics activities in the classroom showed that these constraints were not, in fact, a limitation since the schools were equipped with computers and have internet access. Both groups agree that "The training courses available to address bioinformatics are still scarce". Adding to this, all the teachers from Group A showed interest in attending a training course in this scientific field. Regarding Group B, teachers' perceptions about their knowledge concerning bioinformatics increased during the training course. These results underline the importance of teachers' training to enhance their skills and encourage innovation in their teaching practices. Altogether, these data concerning teachers' perceptions about bioinformatics and its curricular relevance, calls for didactics' initiatives aiming to integrate bioinformatics activities into elementary and secondary education practices.

**Keywords:** bioinformatics activities; secondary school level; interest; teacher training; teaching.

### Resumo

Os avanços científicos atuais evidenciam a necessidade de atualizar as práticas de ensino das Ciências. Neste estudo investigaram-se as perceções dos professores relativamente à bioinformática. Um questionário foi aplicado a dois grupos de professores de Ciências. Os professores do Grupo A (n=11) completaram o questionário previamente à formação para implementarem a atividade de bioinformática "Genomas: utilização de ferramentas de bioinformática na sala de aula para identificação de genes". A análise dos dados recolhidos contribuiu para a preparação de recursos educativos (<https://bioinformaticaula.wixsite.com/bioinformatica-pt>), assim como para o melhoramento do instrumento de recolha de dados. Uma versão melhorada do questionário foi aplicada ao Grupo B (n=13), constituído por professores que frequentaram a ação de formação "Adequação de ferramentas bioinformáticas ao 3.º Ciclo do Ensino Básico e ao Ensino Secundário" (CCPFC/ACC-88413/16) na

Faculdade de Ciências, UP. O IBM SPSS foi usado para analisar os dados quantitativos e a análise de conteúdo para os dados qualitativos. Todos os participantes revelaram um elevado interesse na bioinformática, reconhecendo a sua importância na investigação, e reforçando os benefícios de introduzir esta área científica no ensino básico e secundário, devidamente contextualizada nos currículos. As dificuldades mencionadas pelos professores no que se refere à dinamização de atividades de bioinformática em sala de aula são maioritariamente de ordem logística: falha na ligação à internet ou falta de computadores. No entanto, as observações efetuadas aquando da implementação das atividades nas escolas mostraram que estes constrangimentos não constituíram uma limitação, uma vez que as escolas que participaram no estudo estavam equipadas com computadores com acesso à Internet. Ambos os grupos concordam que “A oferta de cursos de formação na área da bioinformática é escassa”. Os professores do Grupo A revelam interesse em frequentar ações de formação nesta área. No Grupo B, a perceção dos professores relativamente aos seus conhecimentos em bioinformática foi a de que aumentou durante o curso de formação, o que reforça a importância das ações de formação no encorajamento e no reforço das competências dos professores para inovarem nas suas práticas pedagógicas. No seu conjunto, os dados relativos às perceções dos professores relativamente à bioinformática e à sua relevância curricular, surgem como um contributo para promover iniciativas didáticas centradas na integração de atividades de bioinformática no ensino básico e secundário.

**Palavras-Chave:** atividades de bioinformática; ensinar; ensino secundário; formação de professores; interesse.

## 1 Introduction

Nowadays, biological research is strongly benefiting from recent technological advances. In fact, the algorithms for analyzing biological data have become more sophisticated and the performance of computers are continuously improving, allowing a deeper analysis of data (National Research Council, 2005). Due to this new paradigm, the importance of bioinformatics is being highlighted among the scientific community. Bioinformatics can be defined as “the science of how information is generated, transmitted, received, and interpreted in biological systems” (Ramsden, 2009) or, more briefly, “the field of study that uses computation to extract knowledge from biological data” (Nature, 2018).

This field of research highlights the importance of updating science teaching practices to give students a glimpse of daily research routines in bioinformatics (Wefer & Sheppard, 2008). In this regard, several studies have been published underlining the benefits of including basic bioinformatics in secondary level curricula (Cummings & Temple, 2010; Machluf et al., 2017; Magana, et al., 2014). Moreover, European and International initiatives have been developed to work with educational agents, policy makers and students aiming to adequate the educational resources to updated scientific practices (NBIC, 2009; Wood & Gebhardt, 2013; Marques et al., 2014; Workshop FCUP, 2017; Martins et al., 2018).

In fact, the role of the research institutions supporting this change is crucial. Research centers and universities have the know-how, the workforce and the facilities to provide teachers with knowledge and skills, namely, through the promotion of lectures or training courses. These initiatives contribute to rise perspectives on innovation in teaching practices by updating educators with the current biological research tools (Koch & Fuellen, 2008; Attwood, Blackford, Brazas, Davies, & Schneider, 2017).

Following a bottom-up approach, this study acknowledges teachers as instrumental agents of educational changes, and therefore believes that their cooperation and commitment are essential to successfully implement new activities in their classes. To mobilize teachers it is absolutely necessary to provide educational resources capable to scaffold innovative teaching practices in order to release teachers from the cumbersome preparation of activities, namely by assessing the didactics potential of different bioinformatics tools; by designing detailed guidelines for students; and by proposing curricularly framed inquiry-based learning scenarios suitable to the implementation of bioinformatics-based exercises (Form & Lewitter, 2011; Machluf & Yarden, 2013; Wood & Gebhardt, 2013). In this regard, several curricularly framed bioinformatics activities focused on genome data mining, gene regulation, evolution, food microbiology or proteomics, have been recently proposed and validated (Wefer S. H., 2003; Taylor, Davidson, & Strong, 2014; Fernandes et al., 2014; Arnold, Holman, & Zweifel, 2017;

Martins, Fonseca, & Tavares, 2018). In the last few years, some studies addressing the constraints to integrate basic bioinformatics-based activities in elementary and secondary school level, emphasized that teachers feedback resulting from their experience and pedagogical know-how are particularly important to properly optimize and adequate these activities in the school context (Form & Lewitter, 2011; Machluf & Yarden, 2013; Marques, et al., 2014).

Regardless these contributions, teacher's perceptions about their knowledge in bioinformatics remains poorly characterized. This study focused on gathering data to characterize teacher's know-how and interest in bioinformatics, to identify current training opportunities in bioinformatics for pre-service and in-service teachers, and to make the diagnostics of weaknesses that might undermine the integration of bioinformatics in the classroom.

## 2 Methods

### 2.1 Sample and study context

According to the described aim of this study, two different groups of secondary school biology teachers were studied. One group had no previous training in bioinformatics but were willing to implement bioinformatics activities in their classes (Group A) and the other participated in a bioinformatics' training course (Group B) (Figure 1).

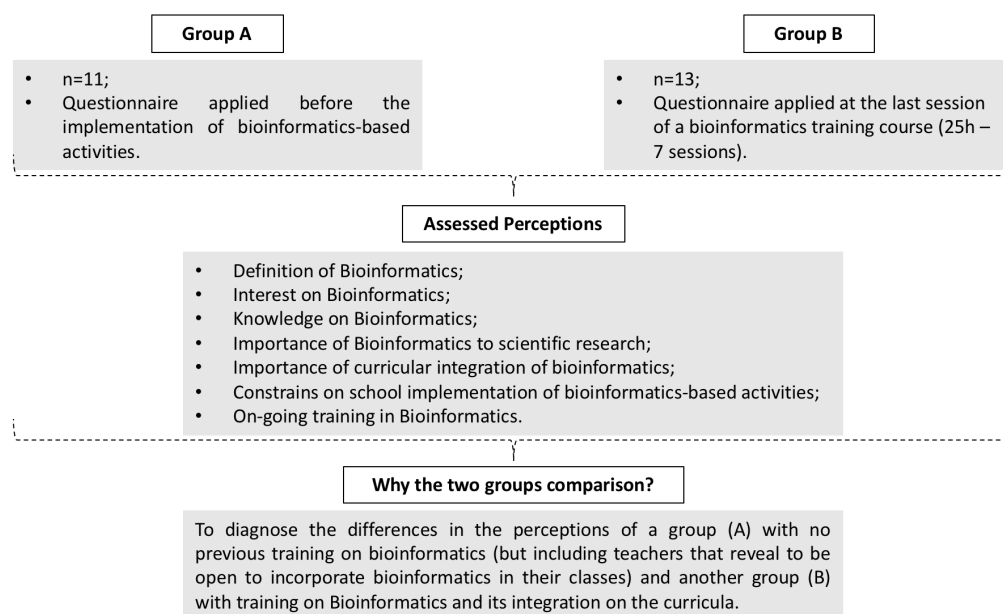


Figure 1: Experimental design.

Group A (n=11) included teachers who accepted to collaborate in the implementation of an activity particularly optimized for secondary level biology classes and designated as “Mining the genome: using bioinformatics tools in the classroom to support students’ discovery of genes” (Martins, Fonseca & Tavares, 2018). Group A teachers belonged to 5 schools, 3 public and 2 private, from Porto and Lisboa (Portugal), during the 2016/17 school year. After the establishment of the described collaboration and having school’s directive board approval, we proceeded with the preparation of the educational resources required for the activity. To make teachers totally comfortable with the proposed materials, they were given the opportunity to make comments and suggest improvements. Moreover, each teacher was previously trained to implement the activity, dismissing any previous doubts they had. Adding to this, teachers were given access to a dedicated webpage to support the classroom implementation of the bioinformatics activity (<https://bioinformaticaaula.wixsite.com/bioinformatica-pt>).

Group B included 13 in-service teachers from 12 schools (10 public and 2 private) belonging to Porto (Portugal) metropolitan area. This group of teachers participated in the first edition of the training course “Adequacy of bioinformatics tools to Elementary and Secondary Education” (2016/17), which is accredited by the competent Portuguese body (register n.º CCPFC/ACC-88413/16) and which took place at Faculty of Sciences of University of Porto ([https://sigarra.up.pt/fcup/pt/cur\\_geral.cur\\_view?pv\\_ano\\_lectivo=2016&pv\\_origem=CUR&pv\\_tipo\\_cur\\_sigla=CFC&pv\\_curso\\_id=13321](https://sigarra.up.pt/fcup/pt/cur_geral.cur_view?pv_ano_lectivo=2016&pv_origem=CUR&pv_tipo_cur_sigla=CFC&pv_curso_id=13321)). The main goal of this training course is to provide teachers with the knowledge and skills to integrate bioinformatics tools and resources in their teaching practices.

## 2.2 Instruments

A specifically designed questionnaire was applied to both groups (A and B) (Figure 2).

Part A
Name (optional): _____
*Name the institution where you obtained your Professional degree for teaching: _____
*Year when you obtained your Professional degree for teaching: _____
Name the school where you are currently teaching: _____
Name the subjects you are currently teaching: _____
School level(s) you teach: _____
Contacts: Phone number _____ Email address: _____@_____.

Part B
<b>Q1:</b> What is <i>Bioinformatics</i> for you?
<b>Q2:</b> Do you think that bioinformatics-based activities are more suitable to be framed: (a) in the Biology curricula; (b) in the Information and Communications Technology (ICT) curricula; or (c) in both Biology and ICT curricula.
<b>Q3:</b> Rate your interest in bioinformatics: 1 (Not interested at all) – 5 (Very interested)
<b>Q4:</b> Rate your knowledge regarding bioinformatics: 1 (Insufficient) – 5 (High)
* <b>Q4:</b> Rate your knowledge regarding bioinformatics: (a) Before the training course: 1 (Insufficient) – 5 (High); (b) After the training course: 1 (Insufficient) – 5 (High)
<b>Q5:</b> From your point of view, is bioinformatics important for the current scientific research?: 1 (Not important at all) – 5 (Very important)
<b>Q6:</b> In your opinion, are bioinformatics-based approaches important in the elementary school level?: 1 (Not important at all) – 5 (Very important)
<b>Q7:</b> In your opinion, are bioinformatics-based approaches important in the secondary school level?: 1 (Not important at all) – 5 (Very important)
<b>Q8:</b> Do you frequently use computers/tablets in the classroom? Yes ___ No ___
* <b>Q8.1:</b> If so, please indicate how frequently <u>in a school year</u> do you use computer resources in the classroom: 1 (Never) – 5 (Very often)
<b>Q8.2:</b> If not, please indicate the main reason(s) why you did not frequently use computer/tablets in the classroom.
<b>Q9:</b> Have you explored bioinformatics tools by yourself in order to implement bioinformatics-based activities in your classes? Yes ___ No ___
<b>Q9.1:</b> If so, did you implement the explored resources in the classroom? Yes ___ No ___
<b>Q9.1.1:</b> If not, please indicate the main reasons why you do not implement the resources in the classroom.
<b>Q10:</b> From your point of view, please list the main constraints regarding the implementation of bioinformatics-based activities in the classroom.
<b>Q11:</b> Do you think that your school/institution has the needed conditions (computers and internet access) to explore bioinformatics tools in the classroom? Yes ___ No ___
<b>Q12:</b> Please rate your agreement with the following sentences - 1 (I totally disagree) – 5 (I totally agree): (a) My academic background allows me to approach the curricular contents using bioinformatics tools; * <b>(a)</b> My initial training at the university allows me to approach the curricular contents using bioinformatics tools; (b) Students are acquainted with bioinformatics and its resources; * <b>(b)</b> My professional training allows me to approach the curricular contents using bioinformatics tools; (c) Preparing a class using bioinformatics tools requires more time and resources than preparing other practical classes; (d) Performing a class using bioinformatics tools is more time consuming than preparing other practical classes; (e) Training courses for teachers in bioinformatics are still scarce.
<b>Q13:</b> Would you be interested in attending more training courses/workshops promoted by research groups which use bioinformatics tools in their lab routines? Yes ___ No ___
** <b>Q13:</b> Please list the main difficulties that you found while performing the activities proposed in the training course.
** <b>Q14:</b> Please make suggestions for improvements that you consider important concerning the activities of the training course you are attending.
** <b>Q15 = Q13</b>
** <b>Q16:</b> Do you accept the inclusion of your email in the mailing list of MDE/CIBIO-InBIO and FCUP to receive information regarding future training courses?

Figure 2: Questionnaire used in the study.

Items highlighted green (\*) were rephrased taking into account Group A teacher’s feedback to improve the comprehension of these items and were included in the questionnaire given to Group B teachers. Items highlighted blue (\*\*) were added to the questionnaire given to Group B teachers.

The questionnaire includes three parts. Part A was aimed to collect data regarding socio-demographic characterization of the sample. Part B covered the assessment topics regarding teachers’ university training and academic background, their attitudes towards bioinformatics and their perceptions about the availability of bioinformatics resources. Part C included three additional items to assess teacher’s opinions about the questionnaire objective, the comprehension of the items, and an open-space to make suggestions for improvement (these items are not displayed in Figure 2).

## 2.3 Data collection

The initial version of the questionnaire was applied to Group A before this group got training and support to implement the bioinformatics activity in their classes. Teachers answered the questionnaire during a get-together session involving all the collaborating teachers *per* school. This survey was important to improve the questionnaire as a data collection instrument. The improved version of the questionnaire, which included new (\*\*Q13, \*\*Q14 and \*\*Q16) and rephrased items (Q4/\*Q4, \*Q8.1. Q12 – (a), \*(a), (b), \*(b)), was applied to Group B during the last session of the training course. It is important to add that the feedback from Group A teachers gave an important contribution to prepare teaching materials, which were made available in the “Teaching Resources” section of the webpage-Bioinformática na Sala de Aula (<https://bioinformaticaaula.wixsite.com/bioinformatica-pt>).

## 2.4 Data analysis

Data analysis included the use of quantitative and qualitative techniques using a mixed-method approach to increase the consistency of the analysis (Punch, 2009). IBM SPSS version 24 was used to analyze the quantitative data. Descriptive statistics included the non-parametric tests Mann-Whitney Test and Wilcoxon Signed Rank Test (Pallant, 2007). Qualitative data was analyzed according to content analysis procedures. In the open-access answers (Q1, Q8.2., Q9.1.1., Q10, \*\*Q13, and \*\*Q14) a content cloud analysis was carried out to have a quick view of the most frequent notions mentioned. This technique was performed using *Wordle* (available at: <http://www.wordle.net/>) as a research adjunct tool of research according to previous studies (Cidell, 2010; McNaught & Lam, 2010).

## 3 Results and discussion

This research was based on an experimental design, detailed in Figure 1, conceived to optimize an instrument to assess teachers’ perceptions about bioinformatics. Most importantly, this study gathers data regarding teachers’ perceptions and interest about bioinformatics, contributing to orient new teaching practices and to identify learning opportunities for secondary education in this field.

### An instrument to assess teachers’ perceptions about bioinformatics

The questionnaire given to teachers from Group A allowed to collect data concerning this instrument in order to make an improved version with new (\*\*Q13, \*\*Q14 and \*\*Q16) and rephrased items (Q4/\*Q4, \*Q8.1. Q12 – (a), \*(a), (b), \*(b)), focused on questionnaire comprehension and to further potentiate its utility for future assessments. Regardless the modifications based on teachers’ critical appraisal of the questionnaire, the participants of Group A considered the instrument objective ( $M=4.45$ ;  $SE=0.21$ ) and easy to understand ( $M=4.82$ ;  $SE=0.12$ ) in a five-point Likert-type scale, therefore validating its utility as an assessment tool of teachers’ perception about bioinformatics.

Four participants mentioned the need to change the expression *academic background* in the sentence “My academic background is adjusted to the requirements to teach using bioinformatics tools, when adequate” (see Figure 2 – Q12 – (a)). The term was replaced by *initial training at the university* (see Figure 2 – Q12 – \*(a)). Furthermore, it was acknowledged the comments made by 4 teachers who highlighted the importance to distinguish their university training (i.e. pre-service), which for some was over two decades ago, from the attendance of training courses and workshops they got more recently, i.e. as in-service teachers. In this regard a new item was added: “My professional training is adjusted to the requirements to teach using bioinformatics tools, when adequate” (see Figure 2 – Q12 – \*(b)).

Three participants suggested adding a Likert-type scale to the question: “Please indicate how regularly in a school year do you use technology in your class activities”, since it was easy for them recall these teaching interventions, and simultaneously help to quantitatively measure this item. The Likert-type scale added was from 1 (Never) to 5 (Very often) (see Figure 2 – Q8 – \*Q8.1.).

Two participants referred that open-ended questions (Q1, Q8.2., Q9.1.1., and Q10) should be reduced or, alternatively, replaced by multiple choice questions. Considering that the number of “no answers” was low (“No answer” frequency: 3/11) and that all the participants of Group A answered

the questionnaire on time and easily, we decided to keep the number of open-ended questions of the questionnaire. In addition, most of these open-ended questions revealed to be particularly useful for a qualitative assessment through content analysis of teachers' knowledge (Q1); their opinion about the curricular framing of bioinformatics activities (Q2); and the constraints to implement bioinformatics exercises in classroom (Q10).

Interestingly, one participant from Group A, who was particularly concerned with paper waste that these questionnaires may imply, suggested the adoption of a digital version of the questionnaire. Although proposed as an eco-friendly solution, the fact is that a digital version might contribute to rapidly increase the sampling universe, thus permitting more robust assessments. This was a particularly pertinent suggestion that will be taken into account in further studies.

Four participants referred not to have suggestions for improvements.

After analyzing the suggestions and the answers of the Group A version of the questionnaire, it was also decided to make the following extra changes to better characterize the participant teachers: sample characterization data (Figure 2 – Part A – *\*highlighted information*): it was added a blank space to indicate the year when teachers obtained their professional degree for teaching. This information is important to better characterize their teaching experience and simultaneously to gather data about the impact their academic training had on a relatively new field that is bioinformatics. Some questions particularly dedicated to teachers that attended the training course (i.e. Group B teachers) were added to the questionnaire (*\*\*Q13, \*\*Q14, \*\*Q16*). These questions aimed to improve the training formation in order to better meet teachers' needs regarding the inclusion of bioinformatics activities in their teaching.

### Findings on teachers' perceptions

*Bioinformatics definition and importance.* Regarding the definition of bioinformatics (Q1), the teachers from both Groups A and B revealed to have a correct notion when compared with definitions from experts of this scientific field (Ramsden, 2009; Nature, 2018). A content cloud analysis, limited to 20 words, taking together the answers of the two groups (A and B), reveals that, in general, all participants relate bioinformatics with the use of computers, which they considered to be crucial to analyze rapidly and effectively biological data sets (Figure 3). This result suggests that, even without bioinformatics training, the teachers are well acquainted with bioinformatics as an important tool to obtain meaningful interpretation of biological results.



Figure 3: Content cloud of teachers' definitions of bioinformatics (analysis limited to 20 words, participants of Group A and Group B were considered together, n=24).

This result is likely related with teachers' interest in this field (Q3). In fact, it can be concluded that teachers of both groups revealed to have a high interest in bioinformatics and were motivated to explore this area (Figure 4) ( $U = 60.00$ ,  $z = -0.76$ ,  $p = 0.45$ ,  $r = 4.9$ ). Moreover, teachers agree on the importance of bioinformatics for current scientific research (Q5) ( $U = 66.00$ ,  $z = -0.92$ ,  $p = 0.36$ ,  $r = -0.19$ ). These findings reinforce previous studies which mention the motivation of teachers to learn more about bioinformatics in order to engage their students in up-to date scientific areas (Kovarik, et al., 2013; Wood & Gebhardt, 2013) (Figure 4).

*Teachers' Perception about their Knowledge of Bioinformatics.* Group A teachers tended to disagree that their academic background (Q12 - a) allows to approach the curricular contents using bioinformatics tools. In Group B, although the *initial training* and *professional training* were analyzed separately (Q12 - \*a; Q12 - \*b), the results were not significantly different from the ones obtained with Group A (Figure 5).

Participants of Group A and Group B admitted to be insecure about their knowledge in bioinformatics before the training, i.e. for Group A before implementing the bioinformatics activity "Mining the genome", and for Group B before the training course (Q4; \*Q4 - a) (Figure 5). This lack of confidence has been previously reported and highlights the need to train teachers in this field (Dalpech,

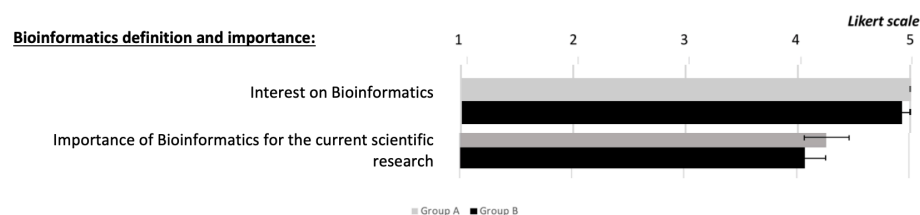


Figure 4: Assessment of teachers' interest in bioinformatics and its importance for scientific research. Bars represent mean with standard error.

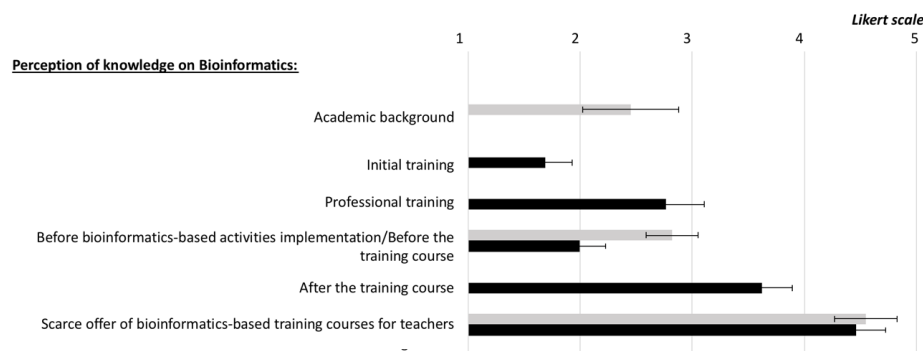


Figure 5: Assessment of teachers' perceptions regarding their knowledge on bioinformatics. Bars and error bars represent mean  $\pm$  standard error. \*Statistically significant different ( $p < 0.01$ ): Group B Before the training course x Group B After the training course.

2006; Kovarik, et al., 2013; Wood & Gebhardt, 2013). Furthermore, the bioinformatics training course reported by Martins, Lencastre, & Tavares (2017) revealed to be an important contribution to nurture the enthusiasm of participant teachers about bioinformatics, who end up feeling more confident to implement bioinformatics-based activities in their classes. These results are aligned with a recent study which reports that after a first foray into bioinformatics activities, teachers tend to feel more motivated, confident and able to redesign the didactic-pedagogical goals (Machluf et al., 2017). Not surprisingly, Group B perception of their knowledge on bioinformatics was significantly different after the course training sessions (\*Q4 – b) ( $z = -3.33$ ,  $p < 0.01$ ,  $r = -0.64$ ), further confirming the positive impact on teachers' knowledge but also on their confidence to tackle these matters during their teaching practice.

Knowing that all participants revealed to use computers in their classes (Q8), the two groups were asked about their autonomy to explore and apply bioinformatics tools in their classes (Q9). Interesting, 8 participants from Group A revealed to have autonomously used bioinformatics tools against only 4 teachers in Group B. This result suggests a different profile between the two groups. Teachers of Group A, who decided to collaborate with us to implement in their classrooms the activity “Mining the genome” described by Martins, Fonseca & Tavares (2018), without previous training, revealed a spontaneous initiative to search and explore bioinformatics platforms by themselves. On the contrary, Group B teachers, who apply for a course training in bioinformatics, includes mostly teachers who do not felt this previous confidence and decided to have insights in this field.

Teachers' search for bioinformatics training contrasts with the information given by all the participants (Group A and Group B) about the scarce offer of bioinformatics-based training courses for secondary school teachers (Q12 – e) (Figure 5). The emphasis on the need for more training courses for in-service teachers in bioinformatics has been previously reported, underlying its contribution to enrich the initial academic training described by participants as weak (Ranganathan, 2005; Schneider, et al., 2010; Martins, Lencastre, & Tavares, 2017). When considering both groups together, only 1 participant showed no interest in participating in training courses promoted by research and academic experts who routinely use bioinformatics tools (Q13).



*Adequacy of Bioinformatics-based Activities to the Educational Context.* The majority of participants (8 of Group A and 10 of Group B) consider that bioinformatics fits the biology curricula of secondary level education (Q2). Six teachers consider that bioinformatics can be helpful for both Biology and Information and Communications Technology (ICT) classes of Portuguese secondary level curricula. In fact, bioinformatics is an interdisciplinary area of knowledge integrating biology, mathematics, statistics, chemistry and computer sciences, which makes this scientific discipline particularly suitable to different classes of secondary education. The bioinformatics activity “Mining the genome” (for Group A teachers) and the bioinformatics exercises of the training course (for Group B teachers) were particularly designed for Biology teachers based on a question-driven approach to address issues such as gene regulation and evolution (Martins, Fonseca, & Tavares, 2018), or real-world problems concerning food preservation and safety (Fernandes, Dias, Fonseca, & Tavares, 2014).

Interestingly, although the bioinformatics activities supporting this study were particularly framed for the secondary level curricula of Biology, the participants of both groups (Group A and Group B) considered that bioinformatics is important for secondary school level (Q7) ( $U = 58.00$ ,  $z = -0.91$ ,  $p = 0.36$ ,  $r = -0.19$ ), as well as for the elementary school level (Q6) ( $U = 41.5$ ,  $z = -1.37$ ,  $p = 0.17$ ,  $r = -0.29$ ) (Figure 6). It is important to emphasize that Group B teachers had a clearer vision on how to apply bioinformatics tools in the classroom, suggesting a careful reflection regarding the learning utility of the bioinformatics exercises proposed in the training course and its integration with the curricular contents. On the contrary, this effort was previously carried out by us by making ready to use materials, such as guidelines to students and power point presentations curricularly framed when the activity “Mining the Genome” was proposed to Group A teachers. The leaning importance given to bioinformatics by both groups reinforces the interest of the theme, even taking into account that presently this scientific field is generally absent from the secondary and elementary school curricula worldwide (Wefer & Sheppard, 2008; Wood & Gebhardt, 2013).

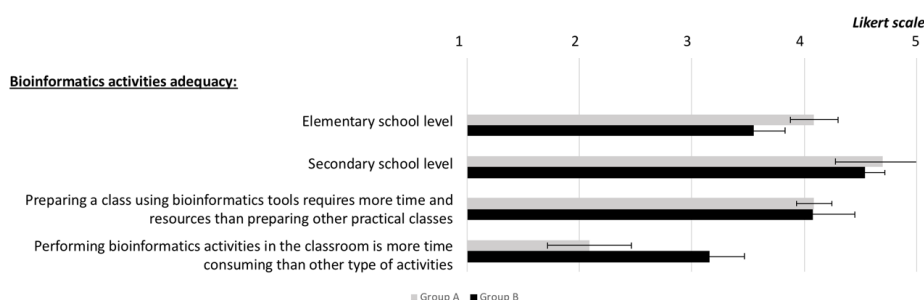


Figure 6: Assessment of teachers' perceptions about Bioinformatics adequacy to the educational context. Bars represent mean with standard error. \*Statistically significant different ( $p < 0.01$ ): Group A Performing bioinformatics activities in the classroom is more time consuming than other type of activities x Group B Performing bioinformatics activities in the classroom is more time consuming than other type of activities.

During this study it was crucial to have an insight on teachers' feedback about the available school resources to implement bioinformatics-based activities in the classroom. The majority of the teachers from Group A (8 out of 11) agreed that their school have the necessary conditions to implement the activity “Mining the Genome” (Q11). In Group B, which was mainly composed with teachers who did not had the opportunity to apply the bioinformatics activities learned during the training course in their classes, are more skeptical about the school resources required to implement bioinformatics exercises. In fact, only 3 out of 13 teachers from Group B considered that schools have the facilities needed for the successfully implementation of bioinformatics activities. The main constrains mentioned by teachers of both groups were coincident (Q9.1.1.) (Figure 7).

The constraints most frequently mentioned were logistics issues, namely, poor internet access, lack of computers and of time to prepare the classes, which were somewhat expected limitations according to the conclusion of other studies on bioinformatics-based initiatives (Wood & Gebhardt, 2013; Marques, et al., 2014). However, the observation record carried out by us when visiting the schools from Group A, showed that these constrains were not impairing the implementation of the bioinformatics activity. Some European studies have been carried out in order to assess the integration





Figure 7: Content cloud of mentioned constraints to apply bioinformatics in the classroom (limited to 10 words).

of ICT in education and to identify improvements and constraints in the implementation of ICT based approaches (Korte & Hüsing, 2006; Snyder & Dillow, 2009; Wastiau et al., 2013). Pointing to a number of policy actions, it is also reported that nowadays schools are generally well-equipped in what concerns to computers availability and internet connection. This information suggests a possibility to implement bioinformatics-based activities in the classroom.

Regarding time constraints to prepare and implement bioinformatics activities to teach science topics, and despite teachers' acknowledgment that bioinformatics might be useful in their teaching practices, teachers of both groups agree that preparing a class using bioinformatics tools requires more time and resources than preparing other practical classes (Q12 – c) ( $U = 57.50$ ,  $z = -0.88$ ,  $p = 0.38$ ,  $r = -0.18$ ) (Figure 6). This result is in line with other studies concerning the implementation of innovative practical approaches in the classroom, namely involving technology to approach scientific issues, as for example biotechnology (Fonseca, Costa, Lencastre, & Tavares, 2012; Martins, Lencastre & Tavares, 2017). The strict teaching schedule, mainly caused by the outsized curricular contents, is pointed out by teachers as a major reason to not diversify the didactic approaches in the classroom (Bryce & Gray, 2007; Fonseca, Costa, Lencastre, & Tavares, 2012). In contrast, when asked if carrying out the bioinformatics activities in the classroom is more time consuming than other type of activities (Q12 – d) the teachers of both groups have a significantly different profile, with Group A teachers being more optimistic than Group B ( $U = 27.5$ ,  $z = -2.62$ ,  $p < 0.01$ ,  $r = -0.53$ ) (Figure 6). Again, the previous preparation of the teaching materials given to Group A teachers and the factual assistance to implement the activity “Mining the Genome”, may have strongly influence their positive attitude regarding the time required to complete the activity in the classroom. On the other hand, although Group B teachers got the training, the basic knowledge and competences to use user-friendly and open access bioinformatics tools in their educational practices (Martins, Lencastre, & Tavares, 2017; Workshop FCUP, 2017), the fact is that these teachers still have to prepare the teaching materials and are unsure about students' performance when facing a new work challenge. The bioinformatics training course attended by Group B teachers was expected to divulge user-friendly bioinformatics resources suitable to be rapidly implemented in the classroom, as suggested by other studies which reported that the majority of the teachers implement hands-on bioinformatics-based activities when have access to them (Wood & Gebhardt, 2013; Shuster, Claussen, Locke, & Glazewski, 2016). Moreover, when teachers are supported by appropriated training, they feel skilled to create their own bioinformatics research-driven exercises, claiming the positive impact of these approaches in their students' learning (Wood & Gebhardt, 2013; Shuster, Claussen, Locke, & Glazewski, 2016). Indeed, Group B teachers had no difficulties when challenged to prepare a bioinformatics activity for their classes. Regardless all these training efforts, Group B teachers' perception regarding the time required to implement some of the learned bioinformatics exercises was not as anticipated, suggesting that providing adequate teaching materials might be essential to raise teachers' receptivity to effectively apply bioinformatics activities in the classroom.

## 4 Conclusion

This study contributed to characterize teachers' perceptions about bioinformatics and to stress its relevance as a didactic tool. The results highlighted are important indicators to foster educational updates aiming to integrate bioinformatics in the elementary and secondary school curricula. Extending this study to a larger universe of biology teachers will be important to consolidate the indicators. Most importantly, in order to promote bioinformatics potential as a teaching tool, more training courses

and workshops on how to prepare the teaching materials will be needed. It is expected, that these and future contributions, might facilitate a bottom-up approach that ultimately might lead to gradually integrate basic bioinformatics contents in science curricular orientations for elementary and secondary level.

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